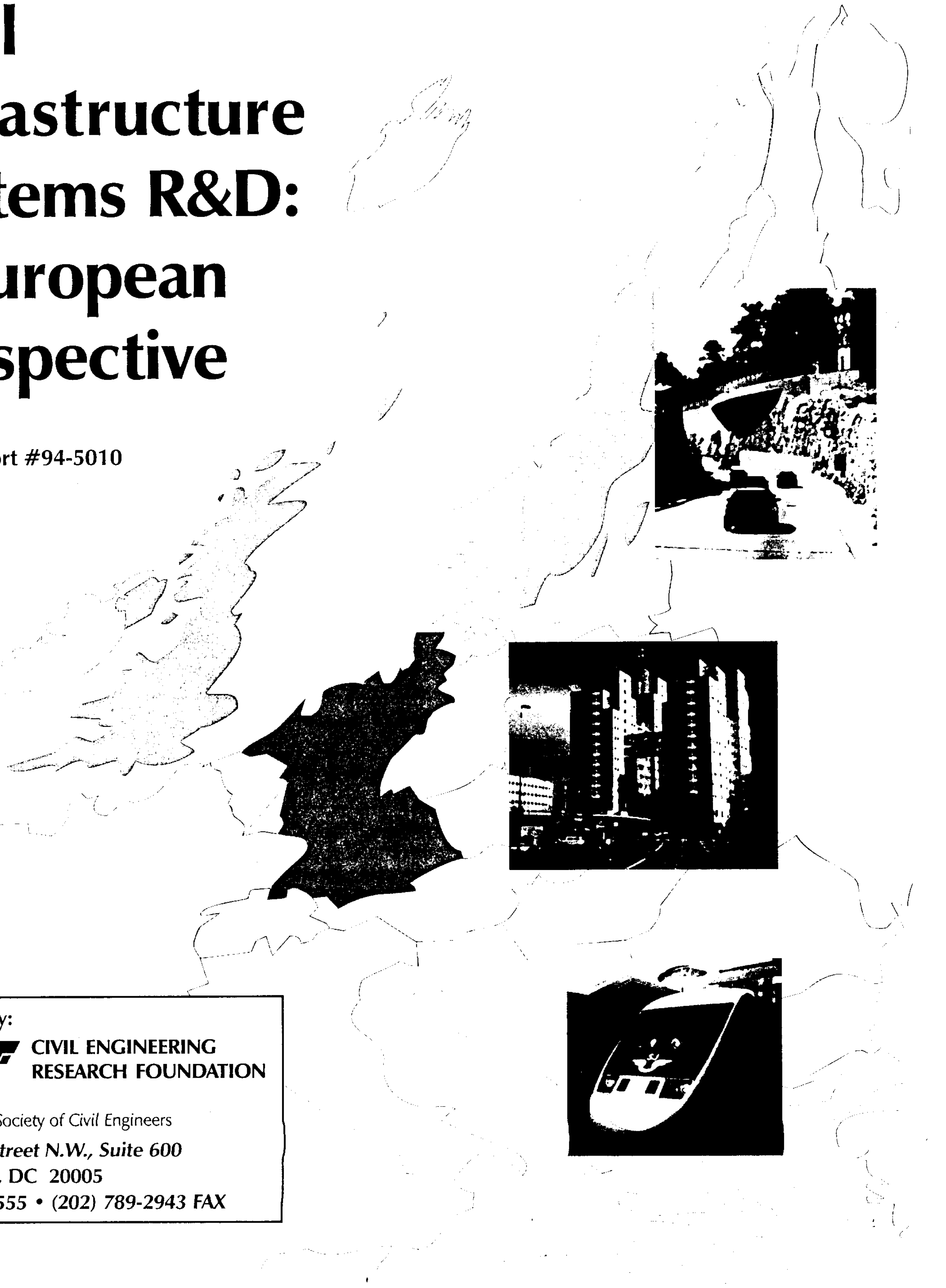
Constructed Civil Infrastructure Systems R&D: A European Perspective

CERF Report #94-5010



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Foreword

This report documents the major findings gathered during a one-week task force trip to western Europe during June of 1993. The task force trip was organized by the Civil Engineering Research Foundation (CERF) in coordination with the National Science Foundation (NSF), which co-funded the study with CERF. Additional funding was provided by the Federal Highway Administration, the U.S. Army Corps of Engineers, and the U.S. Air Force.

During the trip to Europe that is documented in this report, a team of 28 leaders from the construction industry, government, and academia visited six countries, observed a variety of laboratories and construction sites, and met with many private and public sector representatives to gain an understanding of constructed civil infrastructure systems R&D in western Europe.

These visits yielded considerable information. However, the trip's short duration inevitably restricted the depth of the team's exploration. This report is the team's "best effort," rather than a complete in-depth survey and analysis. In some cases, the findings may raise more questions than they answer. The recommendations represent the collective effort of the entire task force and do not reflect the thoughts of any one particular member or sponsoring organization.

The report is intended to provide a baseline for further study. For example, while one of the objectives of the trip was to identify state-of-the-art technologies being used in each country visited, a thorough examination of these technologies is beyond the scope of this report. Rather, exciting new technologies are identified for possible investigation by future researchers.

This current effort draws on the results of two task force trips to Japan in 1991. CERF's Japan International Task Force looked at methods for transferring construction research results into practice. NSF's Japanese Technology Evaluation Center (JTEC) led a trip that examined the latest construction technologies in that country.

Although this report is published by CERF, and has partial sponsorship from NSF, it does not reflect the format and depth of material typically found in other NSF reports, due to the time limitations and extended breadth of this study.

Disclaimer

"This material is based on work supported by the Civil Engineering Research Foundation, the National Science Foundation, the Federal Highway Administration, the U.S. Army Corps of Engineers, and the U.S. Air Force. The government has certain rights to this material. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the U.S. government or any specific member of the CERF Western Europe Task Force."

Acknowledgements

This report reflects the efforts of many construction industry experts, on both sides of the Atlantic Ocean. In addition to the time and expertise contributed by the 28-person task force team members themselves, the Civil Engineering Research Foundation (CERF) is also deeply grateful for the help provided by our gracious European coordinators and hosts. We would like to thank especially those key persons in each country who coordinated meetings and made contacts on our behalf: Paul Alba, CNISF, France; Giulio Ballio, Polytechnic Institute of Milan, Italy; J.N. Bennett, The Institution of Civil Engineers, United Kingdom; Raymond Best, Buchart-Horn GmbH, Germany; Eric Boiteux, SETRA, France; Jan Jerstrom, Bygg & Bo Media AB, Sweden; Tony Knowles, Translink Joint Venture, United Kingdom; Inger-Siv Mattson, Swedish Council for Building Research, Sweden; Luigi Natale, University of Pavia, Italy; and Govert Sweere, Strategic Highway Research Program, the Netherlands. We would also like to thank the members of the European governments, private organizations, and universities who took the time to meet with us and host our visits to their facilities. We appreciate their willingness to assist us in our attempt to further the civil engineering profession.

The trip was co-sponsored by CERF and the National Science Foundation (NSF), with additional funding support from the Federal Highway Administration (FHWA), the U.S. Army Corps of Engineers, and the U.S. Air Force. The National Science Foundation asked the World Technology Evaluation Center (WTEC) at Loyola College in Baltimore, Maryland, to assist CERF in supporting the technology assessment component of the study. WTEC also assisted CERF in the early dissemination of trip results by organizing a follow-up workshop/symposium in the United States in September 1993.

Principal authors of the country summaries include Dr. Richard Tucker, Director of the Construction Industry Institute, University of Texas at Austin; Dr. Andrew Lemer, Principal, Matrix Group, Inc.; Dr. Richard Wright, Director, Building and Fire Research Laboratory, National Institute of Standards and Technology; and Dr. Michael Gaus, Professor, Department of Civil Engineering, State University of New York at Buffalo.

Additionally, I wish to personally thank Dr. Andrew Lemer for integrating observations from all of the countries into the main report body and assisting with final editing of the entire document. Thanks also go to Paul Knapp, CERF Communications Coordinator, and Dr. Neil Hawkins, Head of Civil Engineering Department, University of Illinois, who worked closely with me in organizing and editing this report. Finally, the trip could not have been such a success without Elizabeth Delo, CERF Industry Program Administrator, who worked long hours to schedule all of the trip logistics with our counterparts in Europe, in addition to organizing the CERF Forum in Brussels; and, Melody Spigel, who assisted in creating the itinerary books and sending documents overseas.

Publication of this report was made possible, in part, through contributions by members of CERF's New Century Partnership:

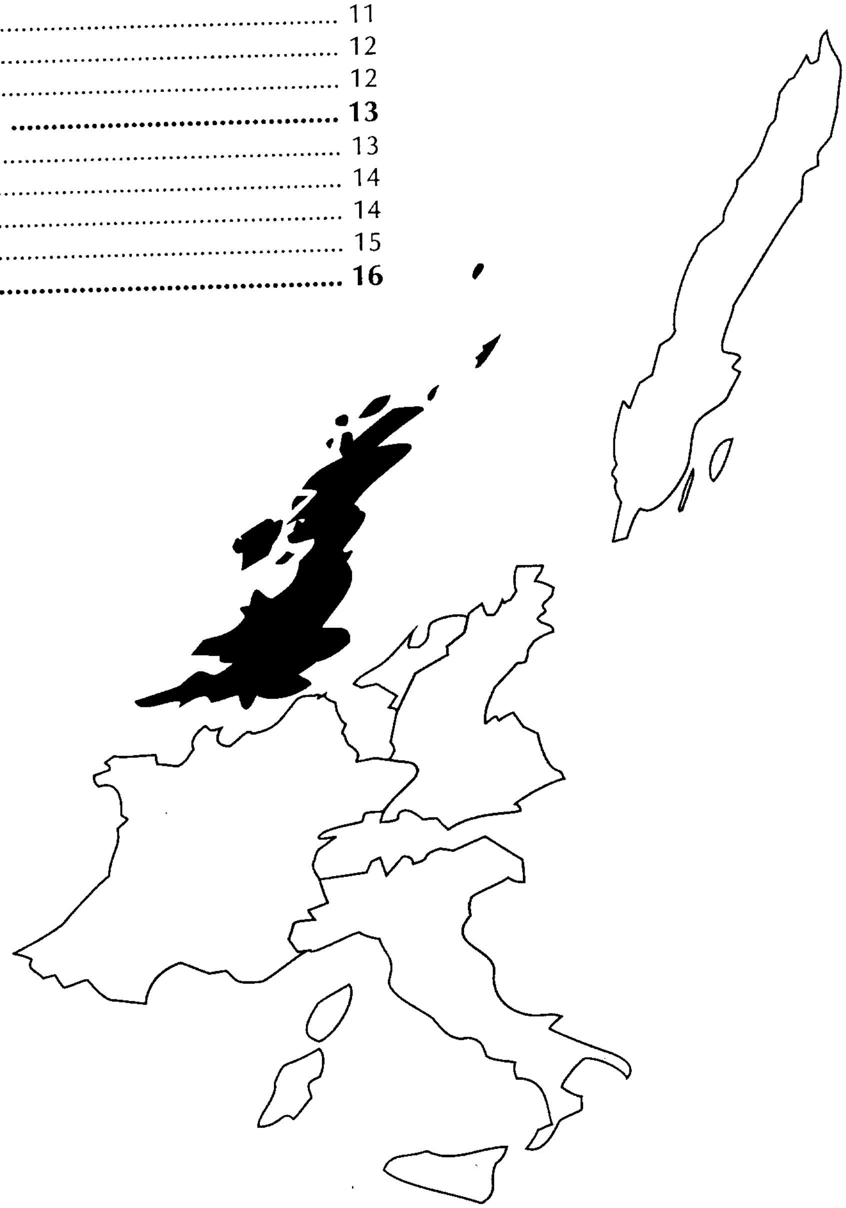
- Charles Pankow Builders
- Parsons Brinckerhoff International, Inc.
- CH2M Hill
- Kenneth A. Roe Memorial Program
- Black & Veatch
- The Turner Corporation

On behalf of the civil engineering profession, I would like to reiterate my thanks to the entire 28-person task force for their efforts in making this report possible. Not only did they work very hard during the very hectic and intense one-week program, they also helped assemble, document, and analyze an enormous amount of information to provide a better understanding of western European CCIS for the global civil engineering profession and industry.

Harvey M. Bernstein

Harvey M. Bernstein, President
Civil Engineering Research Foundation
and CERF International Task Force Chairman and Coordinator

Appendix A
UNITED KINGDOM



Appendix A
UNITED KINGDOM

1. SUMMARY

The United Kingdom is the first western European country to encourage privatization of infrastructure services. Therefore, it is already prepared for the most radical changes likely to result from European unification. However, its environmental standards fall short of some EC directives and will need upgrading. For instance, shipping solid wastes to other countries, which is its current practice, will be severely restricted.

Overall, CCIS technologies are competitive with the rest of Europe. Contractors are increasingly using integrated project information systems, geographical information systems, and CAD systems in everyday operations. The Channel Tunnel project has resulted in some excellent boring and water sealing technologies. Fiber optic strain sensing techniques developed in Germany are being used to monitor the performance of real projects.

The mix of government agencies, private organizations, and academic institutions visited are listed in Table A-1.

TABLE A-1
Participating Organizations—United Kingdom

Organization	Identifier	Type
British Board of Agrément	BBA	government agency
Building Research Establishment	BRE	government research
Building Services Research and Information Association	BSRIA	private research
Channel Tunnel		construction site
Construction Industry Research & Information Association	CIRIA	information services
Department of Environment	DoE	government agency
Department of Transport	DoT	government agency
Imperial College of Science, Technology & Medicine	IC	university
Institution of Civil Engineers	ICE	professional society
Institution of Structural Engineers	ISE	professional society
John Laing Construction		private contractor
Ove Arup & Partners	OAP	private consultant
Science and Engineering Research Council	SERC	government research
Taywood Engineering Limited	TEL	private consultant
Transport Research Laboratory	TRL	government agency
Thames Water Offices		private company
University College, London	UCL	university
Water Research center	WRc	private company

2. CONTEXT FOR CCIS TECHNOLOGY

2.1 *HISTORICAL PERSPECTIVE*

The United Kingdom (U.K.) is a nation composed of England, Scotland, Wales, and Northern Ireland. Fifty-eight million people occupy a country about the size of Oregon (242,000 km^2). This island nation has a rugged coastline that land-borne traffic now pierces via the Channel Tunnel. The weather is moderate and extreme temperatures are rare. Low hills generally dominate the landscape.

With a 1992 gross domestic product (GDP) of US$1,042 billion [DoE, 1992], the U.K. is a leading member of the European Community (EC). Reflecting a long and noble history as the birthplace of the Industrial Revolution and a global source of CCIS innovation, the U.K.'s strong engineering community seeks to maintain leadership in CCIS technologies. The U.K.'s Institution of Civil Engineers (ICE) founded in 1818, has 80,000 members in 140 countries, and the Institution of Structural Engineers (ISE), founded in 1908, has more than 20,000 members. The government's Building Research Establishment (BRE) was founded in 1921 as the world's first national building research laboratory. It was an early and influential proponent of performance

standards that addressed users' needs directly rather than through prescriptive statements for physical properties of construction materials and systems. British professional and trade organizations and governmental institutions remain strong forces in international CCIS R&D.

2.2 ECONOMIC, REGULATORY, AND CULTURAL ENVIRONMENTS

The United Kingdom has made the most of its limited resources and land. As the first industrialized country in the world, it continues to maintain a leadership position in many technology areas. Historically, the U.K. used its technological advantage to colonize underdeveloped foreign lands; it now uses this technological prowess to compete in international markets.

The U.K. economy is growing slowly, with 1 percent growth forecast for 1993, following a 1990–1992 recession. The recession had strongly negative effects in construction firms' R&D, which fell from 0.09 percent of output in 1989 to 0.05 percent in 1990 [DoE, 1992]. As in the U.S., most private sector CCIS R&D is funded by materials and equipment suppliers, and neither designers nor contractors feel they have adequate resources to fund R&D aimed at overall improvements in CCIS performance or design and construction practices.

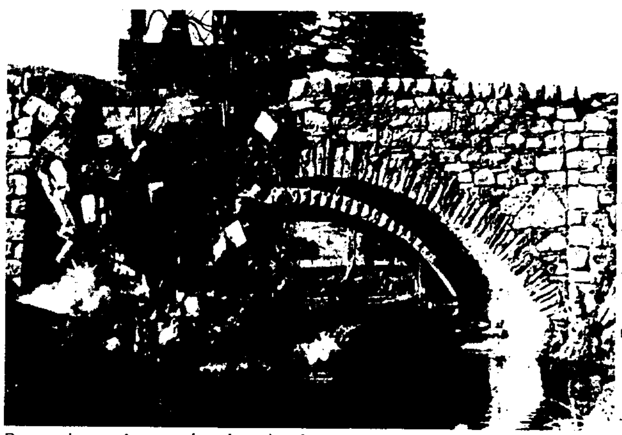


photo courtesy Transport Research Laboratory

By testing aging, redundant bridges to failure, the Transport Research Laboratory can determine whether other structures of similar nature can be allowed to continue in service.

Much of the U.K.'s infrastructure is nearing the end of its design life, needing replacement or refurbishment, and many large cities are becoming overly congested. Consequently the U.K. is looking below ground to relieve the pressure on current transportation systems and facilities. An underground loop around London is being studied and might be financed through private sources. Also ongoing are some of the world's most challenging, and largely privately financed, CCIS construction and renovation projects: the Channel Tunnel, the Canary Wharf urban development, the London Ring Water Main, extensions of the London Underground (subway), and North Sea oil and gas drilling and production platforms. These projects provide many opportunities and strong incentives for continuing innovation.

Funding for CCIS R&D is provided by three government departments. The Department of the Environment currently provides annual funding of US$144 million for environmental, construction, housing, and other research areas. The Department of Transport provides annual funding of US$57 million, with the principal emphasis on inland surface transport. The Department of Trade and Industry funds demonstration projects to assist technology transfer. An interesting point to note is that the Department of Environment regulates the construction industry, while also being responsible for protecting consumers. Some see this as a conflict of interest, but most feel that it effectively balances Department's interests.

The Science and Engineering Research Council (SERC) distributes funding for research at universities and cost sharing with industry. Annual funding is US$28.5 million for construction, US$10.5 million for environment, and US$9 million for marine technology.

In addition to professional organizations such as the Institution of Civil Engineering (ICE) and the Institution of Structural Engineers (ISE), several industry and trade groups are active. The Construction Industry Research and Information Association (CIRIA), founded in 1960, provides best practice guidance to civil engineers that is authoritative, convenient to use, and relevant to their needs. Its members include contractors, materials suppliers, governmental organizations, educational establishments, professional institutions, and trade associations. The Construction Industry Council provides a unified forum and voice for numerous professional organizations concerned with construction. The Construction Industry Environmental Forum, organized by CIRIA, BRE, and the Building Services Research and Information Association (BSRIA), helps the construction industry understand environmental issues, best current practice, and factors which may necessitate new design and working practices. The Standing Committee on Structural Safety, established by ICE and ISE, maintains a continuing review of building and civil engineering matters affecting the safety of structures.

British government policy recognizes CCIS as an important element of the economy and encourages collaborative R&D among industry, research institutes, and universities, with the aim of moving technology quickly and reliably into the marketplace.

2.3 LEGAL AND COMPETITIVE ENVIRONMENTS

Over the past 50 years, the U.K. has swung from a market economy to a planned economy and back again as the ruling government party has changed. The current strong trend toward privatization of public sector activities has now progressed from what were previously national industries (e.g., airlines and telecommunications) to civil infrastructure facilities and related services. Operations of selected government agencies are planned to follow this trend.

Thames Water, formerly a government authority providing water to 7 million people and sewer services to 13 million people in the London area, was privatized in 1989. The Water Research Centre (WRc), with a staff of 700 and offices in six countries, formerly was a national laboratory. BRE and the Transport Research Laboratory (TRL), while still parts of government departments in 1993, are both anticipating similar spin-offs as private operations. Such agencies receive limited government support during the transition, but are expected to become fully self-supporting within a few years. However, the government departments of which these newly-privatized organizations formerly were a part remain substantial customers for their services, and in some cases reportedly dominate the organizations' attentions at the expense of clients from private industry.

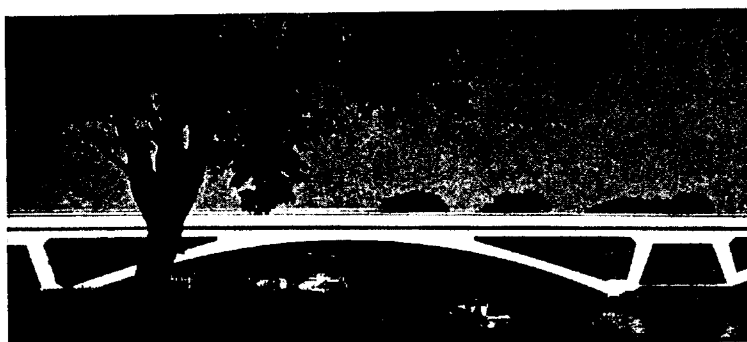


photo courtesy Ove Arup & Partners

The superstructure of the second bridge at Runnymede, designed by Ove Arup & Partners, consists of four balanced frames of prestressed concrete that were cast as half frames on the bank and then slid into their final positions.

British government policy recognizes CCIS as an important element of the economy and encourages collaborative R&D among industry, research institutes, and universities, with the aim of moving technology quickly and reliably into the marketplace. A 1992 DoE report classified research as *basic* (seeking knowledge for its own sake); *strategic* (fundamental, but purposeful); *applied* (problem solving); and *experimental development* (product development). The government's policy concerning public support of research is contained in a recently-issued white paper [HMSO, 1993]. However, this policy emphasizes that construction, which accounts directly for between 6 and 8 percent of GDP and together with the related supply industries for more than 12 percent, has national strategic importance. Construction output is accorded special importance to the efficiency of the nation's economy as a whole, since it represents over half the nation's fixed capital. The white paper notes that low labor productivity results in construction cost increases, and a lack of R&D in new construction technologies leads to poor performance in use. Both effects are cited as having adverse consequences for the nation's economy and international competitiveness, and so justify the strategic importance allocated to CCIS R&D.

The construction industry is still controlled primarily by the architects, but a multi-discipline approach to design is fast emerging. The contracting corps consist of many small firms and a few large companies. Only the largest companies are exploring international markets.

Litigation and liability considerations are more of an obstacle on British construction jobs than the rest of western Europe. Contractors are cautious about introducing innovations and high-risk technologies. Still, litigation problems are small compared to those in the U.S. For instance, team members visiting the Channel Tunnel construction site were not requested to a sign release of liabilities as would be required by many U.S. construction sites.

2.4 R&D AND TECHNOLOGY INNOVATION POLICIES

Presently, only 40 percent of construction related R&D money originates from the government and this percentage is shrinking. Figures A-1 and A-2 display the relative current contributions of British academia, government, and industry to CCIS R&D. The distribution of funding in the first chart will shift more towards industry as more government departments are privatized.

FIGURE A-1
CCIS R&D Funding—United Kingdom

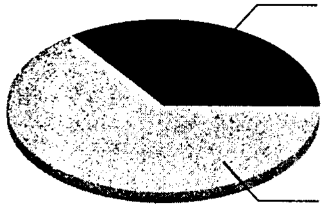
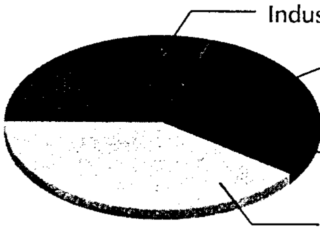


FIGURE A-2
CCIS R&D Performers—United Kingdom



Government funding moves through the Science and Engineering Research Council (SERC), which sees construction as a manufacturing process and a major element of Innovative Manufacturing. SERC supports research at field sites to obtain knowledge unavailable from laboratory or simulation studies. SERC also funds major research facilities, which are open to U.K. users from research organizations or industry. These facilities include a six degree of freedom, 15-ton shaking table for seismic studies; a movable anaerobic digestion facility; a geotechnical experimentation site; a wave generator and coastal engineering model; and a flood flow modeling facility.

As a major element of its fourth Corporate Plan, SERC is developing an initiative on innovative manufacturing that will be industry-led and responsive to the challenges of managing interfaces, integrating manufacturing with design and processing, and promoting information technology [Science and Engineering Research Council, 1993]. The initiative is intended to identify opportunities for the 21st century and establish a strong strategic research platform. Funding for that Corporate Plan is expected to exceed US$25 million annually. [As of April 1, 1994, SERC no longer exists; the Engineering and Physical Sciences Research Council (EPSRC) assumes many areas of SERC responsibility, including environmental and civil engineering.]

The Construction Industry Research and Information Association (CIRIA) provides US$4 million funding for research annually. The Construction Industry Environmental Forum, which includes CIRIA, BSRIA, and BRE, provides matching funds for government research funding. However, the Cement and Concrete Association has severely downsized its research funding and limited its services to providing information. The Concrete Research and Innovation Center at Imperial College has been organized to fill the gap left by this change.

Large contractors support internal CCIS research. Laing, a major contractor, supports information technologies and technical research at an annual level of US$480,000 in small, near-market projects. Thames Water funds US$11 million of research annually; that amount is about 0.7 percent of sales.

Limited R&D support comes from professional organizations. The ICE raises from its members US$160,000 annually for research initiation grants, each of about US$8,000 in magnitude, and publishes a newsletter "Research Focus" to inform practitioners of research results. The ISE provides abstracts of research results specially formatted to meet the needs of practicing engineers. The Construction Industry Council raises annually US$400,000 for research policy studies. For example, its recent report *Crossing Boundaries* [CIC, 1993] calls for major changes in education—more demand-driven for engineering and more systematic for architecture.

These organizations are considering advocating a levy on construction payrolls, in the range of 0.8 percent to 1.5 percent, to fund industry research. The government is only likely to support such a levy if it has the backing of parties affected.

The task force team found that U.K. manufacturing and construction enterprises are enthusiastic participants in collaborative efforts.

2.5 PRIVATE SECTOR TECHNOLOGY PARTNERSHIPS

The task force team found that U.K. manufacturing and construction enterprises are enthusiastic participants in collaborative efforts. Examples include the collaboration of five U.K. and five French contractors in advancing construction technology for the Channel Tunnel Project, and the joint support of Thames Water, equipment manufacturers, and a tunneling contractor for the development of advanced tunneling machines for the London Ring Water Main. In addition, British firms are taking advantage of EC research initiatives, which they are using to leverage their own limited investments.

Academia plays a strong role in these collaborations to advance and implement new CCIS technologies. Academic researchers work closely with practitioners, helping prepare for the actual implementation of new technologies in the field.

SERC's Teaching Company Scheme provides half the salary and academic support costs for recent university engineering graduates or scientists to work for industry on implementing advanced technologies, while in many instances simultaneously gaining advanced degrees. For all industries, about 400 of these partnerships are active at a time. British industry and professional organizations generally provide substantial and sustained political and intellectual support for research in industry, universities, and government laboratories. Strong public demand for improved infrastructure and environmental quality, desire to reclaim land contaminated in earlier industrial development, and perceived needs to meet international competition, within the EC and worldwide, are apparent forces driving CCIS R&D. British government and industry are working to adopt high performance standards for CCIS, incorporating principles of Total Quality Management and ISO 9000 quality procedures.

3. CCIS R&D AND TECHNOLOGY TRENDS

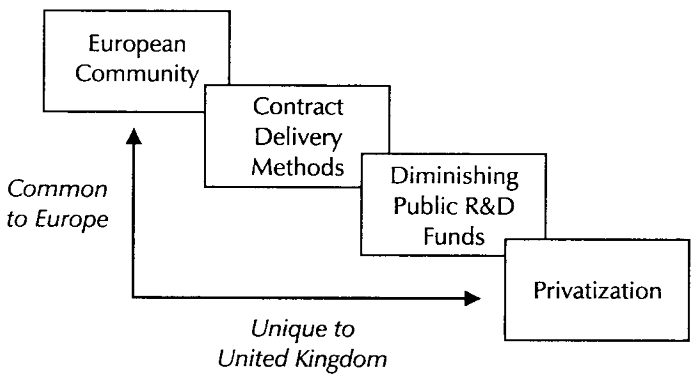
Few new cutting-edge technologies were encountered in the U.K. However, the overall level of new technology applications is high. Computer-aided design is actively used, and integrated information systems make project data readily available in design, construction, and facilities operation and maintenance activities. Geographical information systems, geographical positioning systems, and site positioning systems have all been introduced into practice and are currently being used. Advanced tunneling procedures and high-performance concrete have been used both in the Channel Tunnel and the London Ring Water Main. The U.K. is also active in developing "green" technologies, including energy efficient and "healthy" buildings and use of solid wastes as construction materials.

As to be expected, some CCIS in the U.K. are configured for the type of conditions normally encountered in that nation, and may not be directly applicable to prevailing conditions elsewhere in Europe or the world. For example, during the task force team's visit, unusually warm weather kept daytime temperatures in the mid-80 degree Fahrenheit range. Two major highways and at least one heavily-used commuter rail line were disrupted by heat-induced pavement buckling and track warpage.

3.1 R&D DRIVERS AND ACTIVITIES

In the U.K., construction is experiencing many of the same impacts as in other western European countries. Figure A-3 shows that impending EC unification, new contract delivery methods, and (to a lesser extent) shrinking public R&D funds are significant factors affecting R&D activities in many of the European countries visited. The same figure shows that privatization is an R&D driver producing some effects as yet unique to the U.K. While privatization is a trend in many nations, nowhere has it progressed more than in the U.K.

FIGURE A-3
CCIS R&D Drivers—United Kingdom



European Community

The EC standards and codes will continue to dictate where the U.K. concentrates its R&D efforts for the immediate future. Currently, the environment and transportation activities need the greatest support to meet EC requirements. In particular, innovative methods will be needed for solid waste disposal to meet EC directive procedures.

Contract Delivery Methods

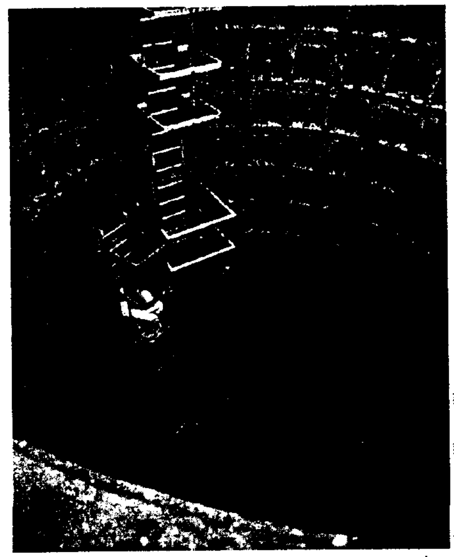
The EC is promoting performance-based specifications, and British contractors are leading the response. Contractors want the freedom to innovate as a means to increase productivity and compete with international companies.

Diminishing Public R&D Funds

The percentage of construction R&D funds provided by government is decreasing as private industry is encouraged by EC directives to sponsor its own R&D. It is anticipated that funding for applied and strategic studies will benefit, probably at the expense of basic research. Life cycle costing of CCIS facilities is being integrated into project design, and this will stimulate more efficient operation and maintenance.

Privatization

As discussed previously, infrastructure services in the U.K. are increasingly being removed from direct government control and placed into private hands. Thames Water and Eurotunnel are both private, for-profit organizations. It was observed that several traditionally public organizations, now converted over to private enterprises, were catching the entrepreneurial spirit and may soon become international competitors.



The London Water Ring Main is a privatized CCIS project due to be completed in 1996.

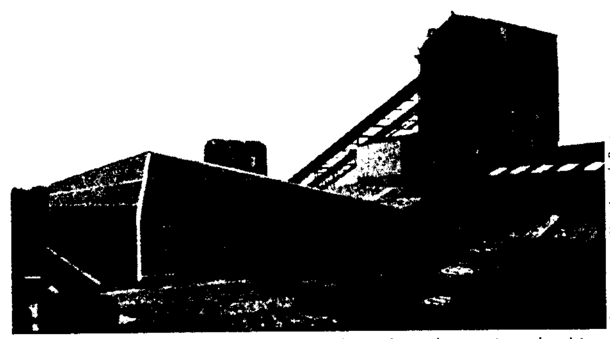
3.2 CONSTRUCTION MATERIALS

Construction materials research, particularly in the Building Research Establishment and university laboratories, is addressing the durability of high alumina cement concretes in buildings, fiber reinforcements for concrete, and rheology of fresh concrete to aid placement. By U.S. standards, high-performance construction materials have already entered the U.K. marketplace [DoE, 1993].

The Channel Tunnel and the London Ring Water Main Tunnel have both utilized durable 150-year service life concrete. Concrete mixes with 90-day compressive strengths of 70–100 MPa were used in the Channel Tunnel. Pipe relining technologies, such as polymer linings, are being implemented for renovating water and sewer pipes. However, team members were not told of any technique, short of digging out, for making connections to renovated pipe.

3.3 COMPUTER-AIDED DESIGN, AUTOMATION, AND INFORMATION SYSTEMS

British contractors are incorporating advanced project information systems into their construction practices. There is substantial and growing use of global positioning systems (GPS) and geographical information systems (GIS), as well as integrated project information systems (IPIS).



Demonstration project testing viability of a solar curing shed in concrete block manufacture.

As in the United States, a variety of private and public databases exist in the U.K. on CCIS technologies, and provide an important source of critically assessed information. The National Building Specification Services Ltd. and the Royal Institute of British Architects Services Ltd. are also working to develop a Specifications Manager and an Annotation Manager which link computer-aided design (CAD) drawings with specification documents, encompassing fully the texts of British Standards manuals held on CD-ROM; this system is similar to one being supported in the U.S. by the National Institute of Building Sciences.

U.K. designers, contractors, and manufacturers are supportive of government policies promoting performance standards. For example, performance standards are used in Scottish highway procurements. The British Board of Agrément (BBA) is the national authority providing the mechanism for evaluating innovations for compliance with performance standards. The European Community recognizes the BBA as the U.K. authority for Technical Approvals.

Design and construction processes, such as computer integrated construction, are receiving increasing attention in the Department of the Environment's research program. Studies of life cycle benefits and costs, including values of quality and costs of failures, are developing information needed for life cycle design.

As mentioned above, advanced computer-based technologies such as GPS, GIS, and IPIS are in use in the U.K. Such systems have been applied to placement of steel frame elements in large structures. Logistics management techniques developed for the Channel Tunnel project have also been employed successfully in the London Ring Main and other projects.

Several contractors are implementing the fiber optics sensing technologies from Germany into real projects. Innovative precasting techniques were utilized on the Channel Tunnel to meet strict tolerances (± 0.1mm).

Some innovative equipment was observed in the laboratories of the Laing Technology Group. A Hall Effect strain measuring device was being used for soil studies, and the use of automatic data logging had substantially increased the efficiency of their laboratory work.

Remedial technologies for contaminated land are important research topics in the U.K. because of its population density and long history of urban development and industrialization. Photogrammetric techniques are being developed for documenting details for historical renovation projects and for decontamination projects. CERF team members were told of large area reclamations controlled with great accuracy via these photogrammetric techniques.

3.4 BUILDING AND CONSTRUCTION SYSTEMS

The British approach construction as a manufacturing process. While team members did not visit any major construction sites other than the Channel Tunnel, their general impression from presentations and discussions was that the levels of technology in the U.S. and the U.K. were comparable.

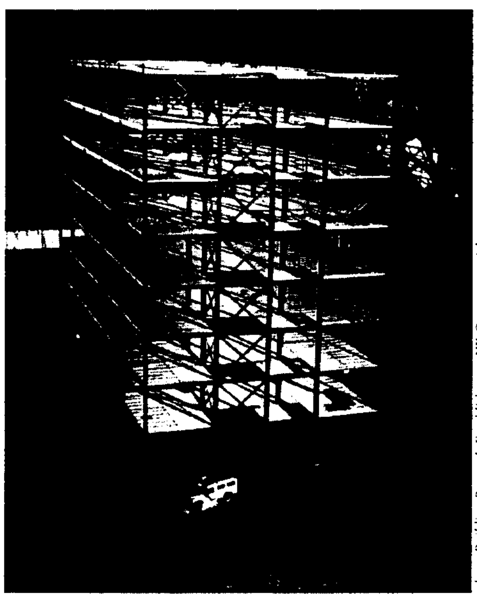


photo Building Research Establishment UK Crown copyright

The eight-story, steel-framed experimental building nearing completion in BRE's Cardington Large Building Test Facility.

Nonlinear and chaotic structural dynamics are being studied at University College, London, with applications anticipated for control of vehicles. Optical fiber strain measurement techniques for monitoring bridges are under development by Laing.

Advanced finite element modeling (FEM) techniques have been developed by Imperial College and applied to control damage to London structures as a result of tunneling. Imperial College has also developed rational damage classification measures for foundation settlements.

The building construction and systems industry is participating in the LINK initiative (Section. 4.1), with a major program on construction maintenance and refurbishment. Over 50 industrial participants are working with 14 science partners on 10 projects in the program's first phase. The total program cost, including government and industry contributions, is estimated at US$10 million from 1988-95, and has as its main objective the development of commercially valuable technologies. Topics being studied include:

- Whole life cost of buildings and building services
- Concrete durability
- Design guides for structural and non-structural building elements
- Services to improve the environment in existing buildings
- Optimization of initial and maintenance expenditures
- Techniques for improving and extending the life of existing building
- Design, management, and training needs for cost-effective maintenance

The Construction Industry Council has requested studies of the performance of buildings as systems. The Building Research Establishment established in March 1993 a full-scale building test facility to support such investigations (photo, opposite page). The Cardington Large Building Test Facility has a 70m by 50m by 1.25m strong floor that can take full-scale experimental structures up to 40m high. It provides unique experimental facilities for assessing or calibrating design methods, and for testing or demonstrating new ideas, materials, and construction methods. Initially, an eight-story steel frame with composite metal deck floors satisfying Eurocode requirements will be studied for static, dynamic, fire, and explosion loading.

3.5 *HIGHWAY AND RAIL SYSTEMS*

Underground transportation technologies are being developed to relieve congestion in urban areas. Rapid repair methods have been developed to streamline the monumental task of maintaining roads.

Much attention is being given to improving both automotive and public transportation. For example, Imperial College is leading a feasibility study, with participation by industry, of underground urban roads. Home employment and telecommunications were mentioned as alternatives to people transportation, but, as in the U.S., such alternatives do not yet appear to affect transportation demands significantly.

photo courtesy Transport Research Laboratory

TRL's advanced condition survey equipment can perform all types of pavement assessment, from analysis of skid resistance to detailed investigations of structural problems in bituminous and concrete pavements.

A number of technological advances were implemented for the Channel Tunnel. Well-controlled factory fabrication yielded concrete tunnel lining segments meeting very stringent tolerances (0.1mm). Each segment was permanently identified by a serial number to allow tracing for any performance problems. Major studies were conducted of the safety and capacity of tunnel ventilation systems, and novel, automated inter-model transfer systems combining rail and highway traffic were implemented at Tunnel ends.

Savings are being achieved by utilizing highway management information systems with a common database. The HERMIS Management System combines inventory inquiries, routine maintenance management, general maintenance budgets, pavement management, graphics, and network studies.

The Department of Transport (DoT) is the principal authority for tunnel roads and highways. DoT conducts research in its own laboratories, and sponsors research in other laboratories. This research is related to: 1) policies for highways, road safety, public transport, marine and aviation safety; 2) its statutory duties related to standards and safety; and 3) purchasing decisions. About half of DoT's R&D deals with highways.

DoT spends about $45 million annually on highway research. Projects include:

- Trials of safety engineering measures
- Road pricing
- Parking strategies for congested urban areas
- Composite plastic materials for bridges
- Reuse of materials, principally in sub-bases

- Noise barriers and quiet pavements
- Long-life pavements
- Rapid curing concrete for repairs
- Geotextiles
- Slope stability
- Upgrading bridge structures
- Contracting process—design/build to bring construction considerations into design
- Education and other measures to improve the safety of young and inexperienced drivers
- Safety features in vehicle design

3.6 ENVIRONMENTAL AND GEOTECHNICAL SYSTEMS

The Channel Tunnel was the test bed for many improvements in boring technologies. Advanced rock tunneling machines were developed for the Channel Tunnel and London Water Ring Main. Thames Water reported that the Canadian manufacturer and the U.K. contractor of the boring machines for the London Ring Water Main developed and implemented those machines in less than one year.

High-performance clay pipes are being tested as an alternative to PVC and iron. The "no dig" and microtunneling technologies used on water network repair/replacement are advanced. The combined sewers are state of the art.

Recycling requirements have not yet been mandated in the U.K. Currently, solid wastes are simply shipped to other countries. However, forthcoming EC codes will make it necessary to devise innovative reuse and disposal procedures. The only recycling observed was the use of waste materials, such as fly ash, in concrete.

3.7 WATER AND SEWAGE SYSTEMS

In the U.K. a primary emphasis is on improving centralized systems for water supply and sewage treatment. While the Water Research Centre and Thames Water showed awareness of concepts for on-site water supply and waste disposal, they gave no indication that they were exploring such concepts. Combined waste water and storm water sewers are customary in the U.K., and there are no strong efforts to eliminate such combined sewers. Fortunately, torrential rains that overload the sewage system are relatively uncommon in the U.K..

Discussions with the Thames Water and the Water Research Centre indicated that major research interests include:

- Impact of absolute standards on water quality and treatment practices
- Advanced membrane technologies to avoid side effects of chemical water treatment
- Process engineering, point of use treatment and new biological treatments for water and waste water
- Water quality measurements
- Odor reduction from sewage treatment
- Toxicology of water treatment

Water Research Centre applications of Total Quality Management (TQM) were cited as the motivation behind the development of a statistical approach to operations and diagnoses of water and sewage systems.

Additionally, "no dig" microtunneling technologies for water and sewer piping are being applied in the U.K., and sewers are being used as conduits for information utilities, such as optical fibers.

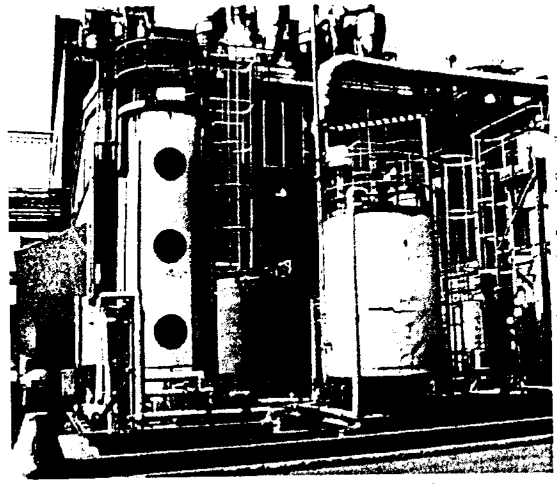


photo courtesy Science and Engineering Research Council

This pilot-scale anaerobic waste treatment plant was developed by five universities and an industrial partner, with funding from SERC, for on-site biological treatment of polluted effluent by industry.

4. STRATEGIES FOR INNOVATION IMPLEMENTATION

4.1 *ROLE OF GOVERNMENT*

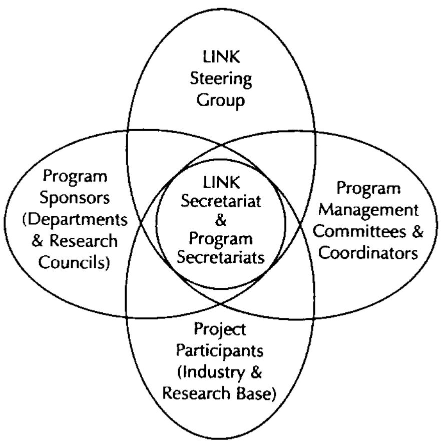
As described previously, British government classifies research in four categories: *basic, strategic, applied,* and *experimental development.* British strategies for CCIS innovation include efforts in all four areas, as well as in moving research results beyond these four stages into practice.

The government white paper referred to earlier [HMSO, 1993] was aimed at resolving "the widely perceived contrast between our excellence in science and technology and our relative weakness in exploiting them to economic advantage." The paper stated several general principles for shaping government support of industrially-oriented R&D:

- The government accepts its role as the main funder of basic research. However, there is a limit to the amount affordable. Research Councils are to support research in appropriate places only—universities, research institutes, and private laboratories. That policy is expected to reduce funding for basic research and benefit strategic and applied research.
- Collaborative research between universities or research institutes and industry is encouraged by providing cost-sharing for research with industry.
- The Science and Engineering Research Council (SERC), which was reconstituted in April 1994 as the Engineering and Physical Sciences Research Council (EPSRC), supports construction-related research.
- The 1972 Rothschild policy is reaffirmed. This policy calls for government laboratories to be supported by paying customers. The private sector Construction Industry Council, however, has cautioned that this policy has led government laboratories to focus their programs on the needs of paying government agencies and neglect the needs of private sector customers, such as architects, engineers, and contractors, that cannot pay for laboratory programs.
- A "Forward Look" (planning) aimed at realizing the potential of technologies resulting from government-supported research.
- The Department of Trade and Industry is to establish "one-stop shops" for delivery of R&D and technology services, particularly to smaller firms. These are similar to the Manufacturing Technology Centers currently promoted by the U.S. Department of Commerce.

FIGURE A-4

The LINK Partnership



The task force members concluded that the U.K. government's efforts on CCIS research were focused mainly on strategic research. The LINK initiative (Figure A-4) is an ongoing government program supporting collaborative research between industry and academia to enable and accelerate commercial exploitation of science and technology. From its start in 1988 through the end of 1991, thirty programs with a value in excess of $420 million had been announced. LINK Programs related to CCIS have received funding totaling $115 million thus far. The LINK program on facility maintenance and refurbishment, for example, has more than 50 industrial participants working with 14 science partners on ten first-phase projects targeting the following:

- Advancing building services
- Concrete durability
- Design guides for structural and non-structural building elements
- Design and operation of services to improve the environment in existing buildings
- Optimization of initial and maintenance expenditures
- Techniques for improving and extending the life of existing buildings
- Design, management, and training needs for cost-effective maintenance and refurbishment

The total cost for this one LINK program, including government and industry contributions, is estimated at US$10 million from 1988-95.

U.K. construction contract delivery systems were not extensively discussed. Members were told that design/build and build/operate/transfer procurements are finding favor as means to integrate the design and construction team, focus their attention on downstream performance, and reduce the duration of construction.

4.2 ROLE OF INDUSTRY

Industrial organizations are valuable transferrers of technology. Memberships in the various CCIS-related professional societies, such as the Institutions of Civil and Structural Engineers, far outstrip memberships in the American Society of Civil Engineers (ASCE) in the U.S. on a per capita basis, and have a worldwide orientation. These societies serve to unite the many voices of civil engineers and focus research resources.

Private companies in the U.K. seek to exploit technologies for their own commercial advantage. They are careful to screen and prioritize research for profitability and risks. The industry uses technological advancements as a basis, other than price, on which to compete. This attitude has resulted in industry promoting performance standards and specifications in CCIS contracts. Further, private companies supply full-time personnel to lead R&D projects at universities. With such industry involvement, applied research is strong in the U.K..

4.3 ROLE OF ACADEMIA

British academicians subscribe to a teaching philosophy similar to Americans. Scientific principles and systematic problem-solving techniques are taught at the expense of professional practices.

University research funding originates from two public sources: the Higher Education Funding Council for England (HEFCE) and SERC. The former supplies general support according to a ranking system based on past research excellence and activity. The latter extends funds to individual researchers and projects.

Academic researchers are at present the primary agents for basic research. The HEFCE is revising how it distributes funds for research to seek enhanced effectiveness. University departments are being ranked in classes 1 through 5 to indicate competence in research, and funding is adjusted accordingly. Class 1 receives no funding. These research funds are particularly prized because they support investigator-initiated research.

The actual construction site is an important laboratory for academic CCIS research in the U.K.

The Civil Engineering Department at the University College of London noted that the U.K. is turning away well-qualified citizens from Ph.D. programs for lack of funding support. This contrasts with the shortage of U.S. citizens interested in postgraduate CCIS engineering education and research.

While academic commitment to basic research and teaching of fundamental principles remains strong, team members meeting with civil engineering departments at University College London and Imperial College found strong commitments to close working relations in research with industry. "Needs-driven" engineering education has been found effective in giving undergraduates motivation and a context for learning. In contrast, graduate education is moving toward a program of formal courses, rather than needs-driven self-study and consultations with tutors. Changes may arise in departmental boundaries, for instance, as civil and mechanical engineering build on their common interests in solid mechanics and structures.

Academia assists in technology transfer to industry through cooperative R&D. LINK projects and SERC's Teaching Company scheme support strong collaborations between industry and academia. Representatives from both industry and academia told the team that technology transfer from university research to practice is effective for CCIS technologies because of long-term cooperative relations and mutual direct involvement in research. The actual construction site is an important laboratory for academic CCIS research in the U.K. However, British researchers noted that technology transfer from academia is less effective for the building segment than the civil engineering segments, primarily because the building industry is less interested in technology and less knowledgeable.

4.4 FINANCIAL INCENTIVES

A central tenet of the U.K. government's economic and technology strategy has been privatization of government industries and agency functions. Privatization is seen as a means to make the U.K.'s R&D establishment more responsive to the marketplace and industry's needs. This strategy appears to be working.

For example, since its privatization, the Water Research Center (WRc) has become an internationally-competitive, high-technology consulting organization and private laboratory. However, university researchers noted that WRc no longer is able to undertake fundamental studies and is less helpful in responding to general scientific and technical requests for information. Architects and engineers in consulting and construction practice also noted that the Building Research Establishment (BRE), slated for privatization, will need to become more responsive to the needs of private industry. Practitioners and researchers expressed concern that BRE's privatization may yield an increase in high-technology engineering services that are already available from laboratories of major construction firms. This could result in reductions in forward-thinking fundamental and strategic research, and in services to small and medium-sized consulting and construction firms that cannot pay for applied research services.

Privatization, uses of performance standards, conformity assessment practices for acceptance of innovations, and research collaborations of government, industry and academia are examples of EC models used in U.K. practice.

For industry-based CCIS R&D, there was an almost exclusive emphasis on problem solving and immediate application of new findings to practice. Examples presented to the team included technology to increase the durability of oil platform structures in the North Sea, analysis methods that reduce design uncertainty and steel requirements for foundation retaining walls, and applications of advanced bridge design methods to building frame analysis. The exceptions to this problem-solving emphasis were cases in which firms found it advantageous to draw on cooperative EC-funded strategic research initiatives.

5. RESPONSE TO EUROPEAN COMMUNITY

The U.K. CCIS community appears to support the European Single Market. However, firms seem to believe that competitors from other EC countries will find it difficult to enter the U.K. market.

British CCIS leaders are active in European standardization, and U.K. policies are implementing EC directives. Privatization, use of performance standards and conformity assessment practices for acceptance of innovations, and research collaborations of government, industry, and academia are all examples of EC models currently used in the U.K.

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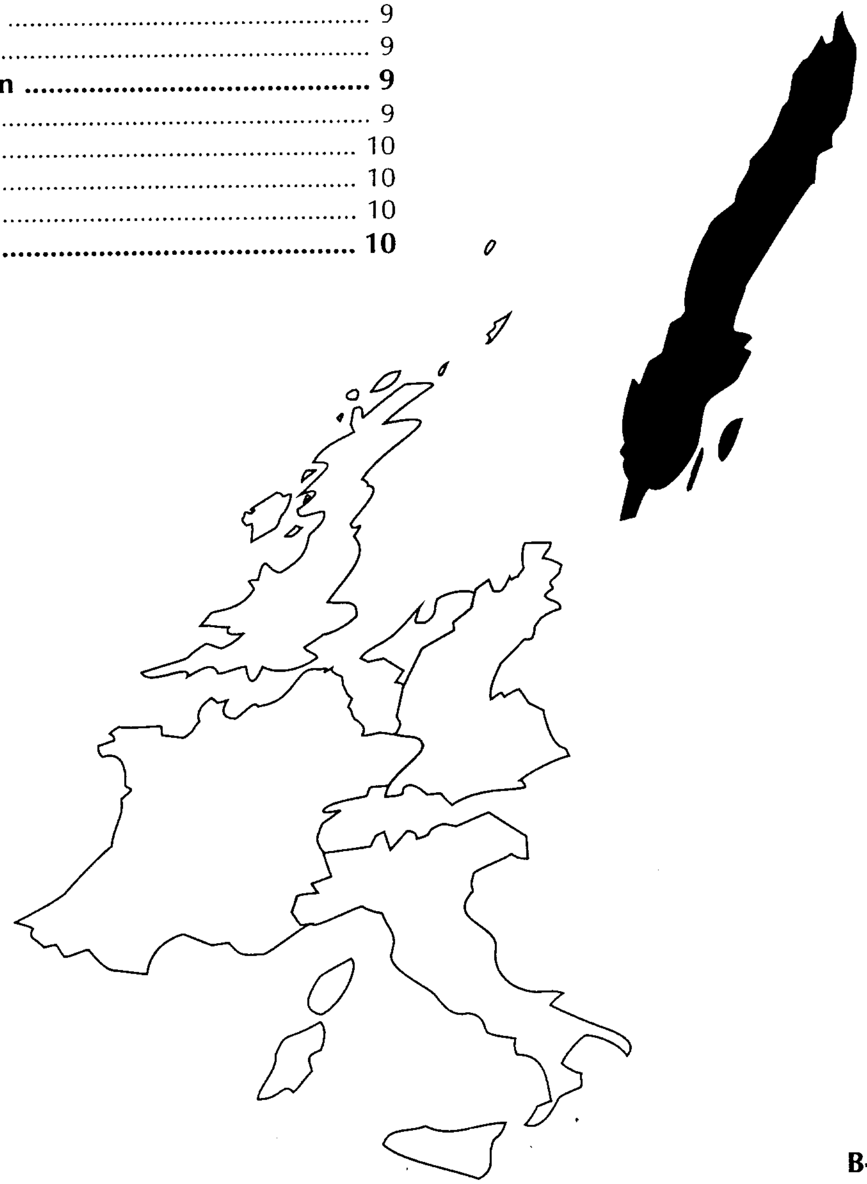
Appendix B
SWEDEN



Appendix B
SWEDEN

1. SUMMARY

Sweden seeks to expand its firms' CCIS markets in Europe and, while not yet a member of the EC, participates in the EC's CCIS forums and anticipates entry to the group. Infrastructure that can enhance trade opportunities with western Europe has high priority for investment and new technology development. This priority is reflected in a variety of current activities aimed at improving Swedish rail and highway networks, ranging from large-scale transportation network investments to enhancement of materials performance. The closely-allied public and private sectors invest heavily in environmental technologies, such as to address problems evident in the acid-rain damage to the nation's forests. Strong environmental values also foster opportunities for enhancing resource utilization efficiency and waste reduction.

Task force teams visiting Sweden were based in the nation's capital, Stockholm, but teams also visited CCIS facilities in other cities. Table B-1 lists participating government agencies, private organizations, and academic institutions in Sweden.

Infrastructure that can enhance trade opportunities with western Europe has high priority for investment and new technology development, as reflected in current activities aimed at improving Swedish rail and highway networks.

2. CONTEXT FOR CCIS TECHNOLOGY

2.1 *HISTORICAL PERSPECTIVE*

The 8.6 million inhabitants of Sweden occupy an area of about 411,000 km^2, similar in size to the state of California, with settlement concentrated primarily in a few urban centers. Much of the nation experiences a sub-Arctic climate, although the southern part of the country is more moderate, with conditions comparable to those encountered in Minnesota. Climate, terrain that becomes rough in the country's western portions, and physical separation from the mainland of Europe are decisive factors shaping Sweden's CCIS investment and technology interests.

2.2 *ECONOMIC, REGULATORY, AND CULTURAL ENVIRONMENTS*

Sweden is an industrialized nation with a relatively high standard of living. An historically strong commitment to social welfare is reflected in an extensive social services system and government spending that has accounted for as much as half of the nation's gross national product (GNP). Changes in government and an extended period of economic recession underlie a current policy emphasis on private-sector development.

TABLE B-1

Participating Organizations—Sweden

Organization*	Identifier	Type
NCC BYGG AB		private contractor
Royal Institute of Technology	BFR	university
Royal Swedish Academy of Engineering Sciences	IVA	private science institute
Skanska Teknik		private consultant
Swedish Council For Building Research		government research
Swedish Geotechnical Institute	SGI	government agency
Swedish National Rail Administration	Banverket	government agency
Swedish National Road Administration	Vagverket	government agency
Swedish Road and Traffic Research Institute	VTI	government research agency

* English translation of organization name provided, where available.

Along with other Scandinavian countries in the European Free Trade Association (EFTA), Sweden aggressively pursues selected export markets as a means of maintaining national income with a small domestic market. Sweden's long-standing international reputation for high technical specialization, advanced design and management methods, and high quality product, combined with the opportunities of a single European market and demands for reconstruction of eastern Europe, are expected to provide strong international markets for Sweden's construction industry. The government expresses keen interest in the European Community (EC) and has applied for membership.

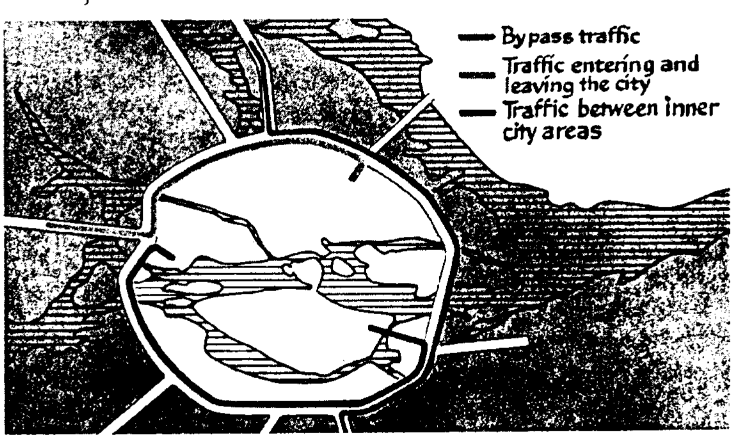
2.3 LEGAL AND COMPETITIVE ENVIRONMENTS

In 1990, Sweden's total construction volume amounted to US$30 billion and the industry employed some 600,000 people. Recessionary declines are expected to have reduced total volume by 25 percent by 1993 and employment by some 100,000 jobs. Residential and commercial construction demand have declined and construction firms report that funds are not readily available to support construction of planned CCIS projects. The larger contractors have turned to Asia and South America to support themselves. The domestic industry is, on the whole, made up of predominantly small companies.

Nevertheless, construction is viewed as an important sector of the nation's economy, and CCIS is viewed as an export market, as well as supporting all economic activity. The Swedish Building and Energy Export Agency has a budget of US$60 million and supports 175 people abroad to market construction products and services. Swedish firms offer manufactured housing in the United States, and have established at least one manufacturing facility in this country (in Oregon).

artwork courtesy Stockholmsleder AB

The Stockholm Ring Road, "Ringen," is intended to improve the environment and increase accessibility within the Stockholm region. Above: more than half of the Ringen will consist of underground tunnels, such as the one depicted in this model. Below: the road's three major subsections.



Investments are being made to serve Sweden's own needs as well. The most substantial of these investments are the US$2 billion Stockholm Ring Road project "Ringen," the US$1 billion annual investment in upgrading the Swedish railroads, and a grand connecting bridge between Sweden, Denmark, and the European mainland. To avoid shortages in the CCIS work force, efforts are underway by the Swedish National Highway Administration to promote education of engineers and to recruit women into the field.

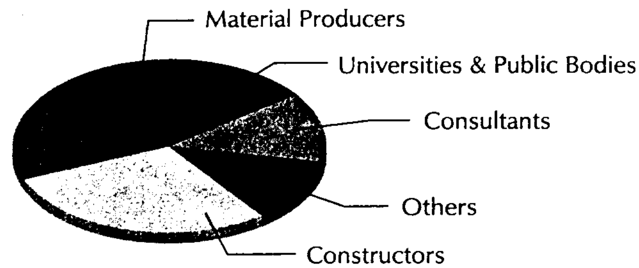
Following the trend in other Swedish public sector enterprise, CCIS and related research services are being spun off through privatization. The Swedish National Rail Administration has been reorganized as a quasi-governmental enterprise responsible for the capital system, while a separate enterprise provides transport services. Both activities are slated for full privatization. The functions of the Swedish Institute for Building Research, formerly a governmental operation, have been assigned to the Royal Institute of Technology and Uppsala University. Privatization is foreseen for the Swedish Road and Traffic Research Institute (VTI).

Labor is an active participant in privatization activities as well as a strong proponent of R&D as a means for enhancing export competitiveness. The Development Fund of the Swedish Construction Industry, created in part at labor's request, is supported by a three-cent-perhour levy on construction employment payrolls that yields US$6 million annually for research. Figure B-1 shows the relative distribution of research funding from this Development Fund to materials producers, constructors, universities, and private consultants.

Professional organizations such as the Royal Swedish Academy of Engineering Sciences and the Swedish Society of Civil and Structural Engineers, as well as major private organizations such as engineering constructors Skanska and NCC, seem actively involved in the government's CCIS policy decisions.

FIGURE B-1

Performers of Swedish Industry Development Fund-sponsored R&D



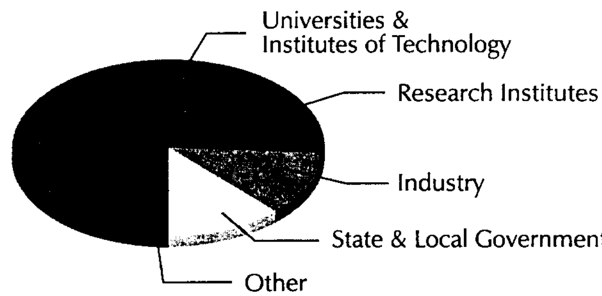
2.4 *R&D AND TECHNOLOGY INNOVATION POLICIES*

The Swedish government supplies 37 percent of the nation's total R&D spending. Much of this spending goes to the universities, research councils, and sectorial agencies.

The government directly funds construction-related research through the Swedish Council for Building Research (BFR), within the Ministry of Industry and Commerce, at an annual rate of US$35 million. Local governments, industry, and research institutes also contribute to the BFR budget. Figure B-2 shows the relative distribution of BFR R&D funds to various research performers.

FIGURE B-2

Recipients of BFR R&D Funding



BFR is reported to be formulating an infrastructure research strategy. Research priorities include infrastructure, information technologies, materials durability and advanced performance, buildings and infrastructure management, "healthy" building design and operations, and new energy sources and efficiency.

2.5 *PRIVATE SECTOR TECHNOLOGY PARTNERSHIPS*

The Swedish National Board for Industrial and Technical Development (NUTEK) provides matching funding for industry research. NUTEK has an annual budget of US$700 million, distributed among academia (51 percent), research institutes (25 percent), and industry (24 percent), to fund technical research and development, materials research, energy research, and bio-engineering research.

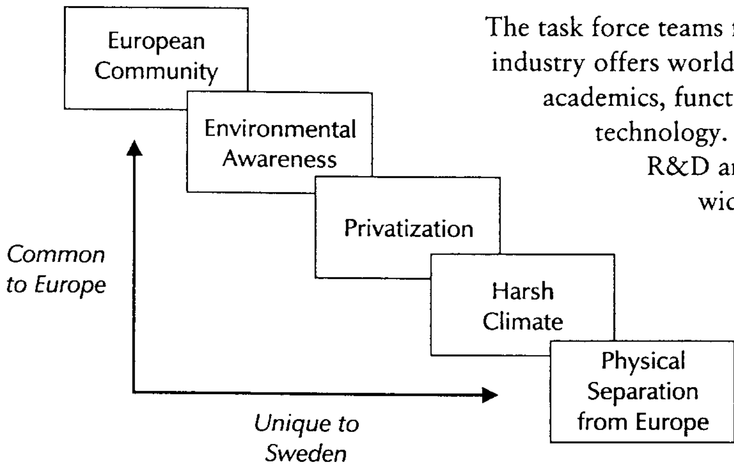
Construction company researchers may apply for grants from the Development Fund of the Swedish Construction Industry. Studies supported by this fund have included use of heated concrete for cold weather placement, measurement of quality failure costs, and development of methods for reducing construction project duration. Task force members were told that Swedish contractors' R&D spending averages 1.6 percent of annual revenue, and that Skanska, the nation's second largest construction firm, is increasing research spending despite company-wide financial losses. Swedish firms are reported also to assign staff to work directly on R&D within universities or government laboratories.

3. CCIS R&D AND TECHNOLOGY TRENDS

The task force team observed several factors that appear to be driving Swedish CCIS R&D and new technology applications. The already advanced level of technology application in Swedish CCIS practice seems likely to continue advancing, due in part to a willingness of CCIS owners and providers to test promising new technology in field applications. While liability is a concern in Sweden, the concern and related litigation appear to present few barriers to innovation. Task force team members observed an attitude of cooperative assumption of risk among owners, designers, constructors and manufacturers, backed by insurance and warranty programs to protect firms willing to undertake well-founded innovation.

FIGURE B-3

CCIS R&D Drivers—Sweden



3.1 R&D DRIVERS AND ACTIVITIES

The task force teams found that despite the nation's modest size, the Swedish CCIS industry offers world class technology, management capability, professionals and academics, functioning at or close to the leading edge in many areas of CCIS technology. As illustrated in Figure B-3, aggressive programs to foster R&D and applications of new technology are being driven by widespread concern for environmental quality, the shift towards privatization of CCIS institutions, the nation's remote location and harsh climate, and the progress of EC formation and European unification. The task force teams found major efforts under way to improve railway systems, road durability and maintenance, energy efficiency of buildings and urban districts, and other aspects of Sweden's CCIS.

European Community

The major firms in Sweden's CCIS industry seek access to the EC market. These firms and government agencies are undertaking to influence and meet EC standards, and to participate in the EC's multinational R&D programs.

Environmental Awareness

Environmental concerns are, for the most part, integrated into a new facility's overall design, but the search continues for "green" technologies such as low-waste construction and operations, and recycling. Cleaning up and building on contaminated land is receiving more attention as well. These environmental technologies are finding ready international markets.

Alternative sources for power generation is another area receiving substantial attention. Sweden's nuclear power plants are to be phased out within the coming two decades, and must be replaced 20 years by other technology viewed as environmentally more benign.

Privatization

Swedish CCIS activities are being privatized to meet EC recommendations and to improve their effectiveness. The Swedish Institute for Building Research was privatized, purportedly to improve its relationship with industry, and the Swedish Road and Traffic Research Institute (VTI) is also preparing for open market operations. The Stockholm Ring Road project, a major undertaking involving substantial tunnelling and likely new ventilation, signage, and guidance technology, is to be financed and operated through private sources. Increasing use of performance specifications and warranted work in public sector projects will effectively shift management responsibility to private contractors.

Harsh Climate

The harsh climate affecting most of the nation influences Swedish CCIS and R&D priorities. Current related efforts include research on higher performance materials, ways to minimize frost heave and low temperature cracking in highway pavements, and improved energy efficiency at all stages of the facility life cycle.

Physical Separation from Europe

Sweden seeks to enhance its transport efficiency by reducing the time and cost of transporting goods across the 1,800-kilometer overland distance that separates it from the other European countries. Railways are being upgraded to accommodate higher-speed operations, and pavements are being monitored to maintain driving quality. R&D studies are being conducted to support these efforts, and the proposed bridge linking Sweden to Denmark and the European mainland is likely to be a significant test bed for new technology.

Sweden seeks to enhance its transport efficiency by reducing the time and cost of transporting goods across the 1,800-kilometer overland distance that separates it from the other European countries.

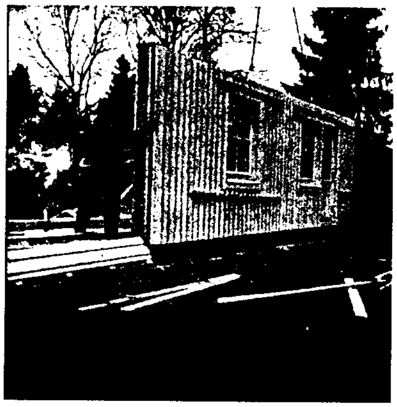
3.2 CONSTRUCTION MATERIALS

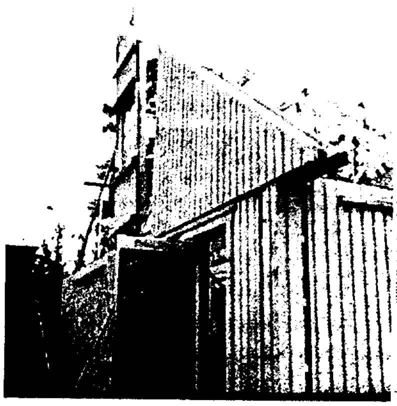
A very large fraction of road mileage in Sweden is paved with asphalt concrete, reportedly because researchers have concluded asphalt is less susceptible to frost heave than Portland cement concrete pavements. Asphalt mix designs further enhance the material's generally desirable characteristics. Stone-mastic asphalt pavements are being constructed for their high durability, and research is also being done on noise attenuation and wearing characteristics of porous-surface pavements. A six-year, US$10 million program on high-performance concrete is being sponsored by the Swedish Cement and Concrete Institute, NUTEK, SIB, and Skanska, with 18 projects focusing on microstructure and physical properties, mix rheology and placement techniques, fiber reinforcement, and fly ash utilization. Fifty-five percent of funding comes from industry, and 45 percent from government. Use of hot concrete for cold weather placement and curing, and uses of fly ash and bottom ash wastes in concrete, are other areas of research receiving substantial attention.

3.3 COMPUTER-AIDED DESIGN, AUTOMATION, AND INFORMATION SYSTEMS

Computer-aided design is widely used, and integrated project information systems make project information readily available to participants in design, construction and facilities operation and maintenance. The Swedish National Road Administration has developed and implemented a user-friendly, computer-aided highway design system that appears to have wide acceptance. The task force teams were told that geographical information systems (GIS), geographical positioning systems (GPS), and automatic site positioning technologies have also been introduced into practice and applied on actual construction projects. For example, a GPS method for site layout has been developed, enabling automatic location of points in the field from the electronic project database (e.g., for positioning individual dwellings in a residential development), and is being used to level large concrete floor slabs. Technology also has been developed to locate electrical cables ahead of an excavator.

A US$1.4 million per year R&D program in information technology in building and property management is supported by the Swedish Council for Building Research (SCBR), the Swedish National Board for Industrial and Technical Development (NUTEK), and the Development Fund of the Swedish Construction





photos courtesy SWEBCO/Swedish Council for Building Research

Less than fourteen hours after starting with a bare foundation, a crew of four (above) completed the shell and partitions of a 1,400 square foot house and made it weathertight (right).

Industry (SBUF). Topics include simulation of buildings and building services, neutral building product model, interface standards for facility management, knowledge-based systems for professional and nonprofessional users (including elderly apartment dwellers). This program is contributing to STEP, an EC program aimed at developing standards for automated exchange of construction industry product information. Professional interactions are maintained with Stanford University's Center for Integrated Facilities Engineering.

Additional research funded by SBUF considers life cycle benefits and costs including values of quality and costs of failures. Skanska, and probably other major construction firms, has work underway to develop knowledge-based systems to support decisions in CCIS and to improve integrated project information systems. The Swedish Work Environment Fund, the Working Life Fund, SCBR and SBUF have studied "Tight Construction Schedules," addressing methods for calculating optimal construction time, a model for assessing the influence of variables on the construction process, and a dynamic model for construction.

3.4 BUILDING AND CONSTRUCTION SYSTEMS

While Sweden is noted as a leader in building technology and asserts leadership in prefabricated housing, task team members observed little of special note in the Stockholm area, either in high-rise or lower-density dwelling construction.

The Swedish Council for Building Research has long funded building systems and construction studies. In recent years much emphasis has been given to energy efficiency and environmental quality. Swedish healthy-building studies include collaborations of medical and building researchers to provide world leadership in indoor environmental quality. District heating studies provide technical bases for efficient central heating, and central heating plants have been developed using waste heat from power generation and industrial processes.

3.5 HIGHWAY AND RAIL SYSTEMS

The planned Stockholm Ring Road, "Ringen," project provides stimulus for substantial highway systems research. A driving simulator based on air pilot training equipment is used to support geometric and driver information system design. Studies are being made of tunnel safety and ventilation systems, and a "smart card" toll collection system is under development. The Swedish National Road Administration is supporting studies of fast-setting concrete for highway repair, social science research on transportation and urban development and a multimodal transportation system analysis method that includes consideration of home employment and telecommunications as alternatives to transportation.

High-speed surface profiling and pavement stiffness measurement equipment (with abilities to cover 200 km per day) has been developed and used by Swedish

Highways (RST), and ground penetration radar is being investigated. A pavement conditioning monitoring system (for wet or icy pavements and for traffic conditions) is being implemented by the Swedish Highway Administration. The Swedish Highway Administration provides pavement management instruction (in English) for officials of third world countries.

The Swedish railway system has placed in service advanced "tilt" vehicles that maintain passenger comfort at higher operating speeds on existing roadbed. Maintaining catenary contact, controlling track-bed vibration and external noise, and addressing passenger complaints of motion-sickness are among the problems continuing to be researched. Continuous-welded rail and prestressed concrete ties are conventional for Swedish railroads, and an extensive program of railroad upgrading and new development has been undertaken. Swedish Rail uses ISO 9000 for its quality assurance programs.

The Swedish National Rail Authority uses automated equipment for rail and tie replacement. The system appears to be state of the art in a field long employing specialized, mechanized equipment. Research is being conducted, focusing on such topics as rail fatigue, geographical positioning systems for support of construction, operation and maintenance, an information system for right of way facilities, soil properties, routing of oversize or overweight loads and developing a code of practice for railroad bridges.

3.6 ENVIRONMENTAL AND GEOTECHNICAL SYSTEMS

Swedish underground construction methods are very advanced, particularly for hard, competent rock. Similarly, environmental protection and remediation practices were judged by team members to be some of the best in the world. Experimentation with ground-storage and extraction of heat is one of the R&D areas that task force team members felt may further advance these practices.

The Swedish lead also in practices for minimizing construction waste and recycling materials.

3.7 WATER AND SEWAGE SYSTEMS

While the task force teams made no significant direct observations, secondary sources available to team members indicate that emphasis continues to be placed on improving centralized systems. The Swedish Council for Building Research reported that environmental quality and waste minimization are major research priorities, with such study topics as on-site water supply and waste treatment facilities, and "supertubes" that serve as conduits for multiple utilities (e.g., water, sewage, gas, electricity, telecommunications).

4. STRATEGIES FOR INNOVATION IMPLEMENTATION

Sweden seemingly relies on a close and active collaboration of all members of the CCIS industry to foster productive R&D activity and innovation. The relatively small size of the country's population and the industry's leadership may strengthen this collaboration's effectiveness.

4.1 ROLE OF GOVERNMENT

Government programs such as NUTEK and the research supported by government agencies provides financial incentives to industry for innovation. NUTEK's projects, however, appear to emphasize generic technologies and do not provide intellectual property rights to participating industries. Much research is privately supported for improving competitiveness in the marketplace, largely because the use of performance specifications encourages innovation.

4.2 ROLE OF INDUSTRY

Contractors are reported to reinvest an estimated 1.6 percent of turnover into R&D, and the construction industry requested government imposition of a payroll tax of $0.03/labor-hour, paid into a Development Fund (SBUF) used to support R&D. In addition to this levied Development Fund, industry's R&D also receives additional government support through the Swedish Board for Industrial and Technical Development (NUTEK), which provides matching resources for industry-initiated research on high-priority projects in such areas as materials, energy, and bioenergy. New technology developed with NUTEK support is non-proprietary.

Privatization, use of performance standards and conformity assessment practices for acceptance of innovations, and research collaborations between government, industry, and academia are examples of EC models in Swedish practice.

4.3 ROLE OF ACADEMIA

Academic researchers maintain close relationships to practitioners, consider requirements for implementation of research-based new technology, and help prepare practitioners for the implementation. Swedish academic researchers told task force team members that their research is transferred effectively to practice through long-standing professional relationships with practitioners and standards organizations.

Leading Swedish universities have been active in CCIS research and the transfer of research results to practice, but changes occurring in academia make the future less certain to be a continuation of past practices. The Swedish Royal Institute of Technology is condensing eleven faculties to five (in some cases going from one full professor per faculty to several). Architecture, civil engineering and surveying are being combined. The formerly governmental Swedish Building Research Institute at Gavle is being transferred to the Swedish Royal Institute of Technology and to Uppsala University. The two universities' activities at the Gavle site will include teaching and research.

Other technical universities involved with construction R&D are Lulea, University of Gothenburg (Chalmers), and Lund. The majority of their funds come from the government, with only a small percentage coming from industry.

4.4 FINANCIAL INCENTIVES

Private researchers submit proposals for grants from the $US 6 million collected annually by the SBUF. Companies can use this research money to improve their technology, enabling them to use of superior, more cost-effective solutions that conform with set performance specifications.

5. RESPONSE TO EUROPEAN COMMUNITY

While not yet a member of the EC, Sweden does appear to support the European Single Market concept. Swedish CCIS leaders are active in European standardization and Swedish policies are implementing European Community directives. Privatization, use of performance standards and conformity assessment practices for acceptance of innovations, and research collaborations between government, industry, and academia are examples of EC models in Swedish practice.